How well do global climate models simulate the transport of momemtum, heat and moisture into the California region?

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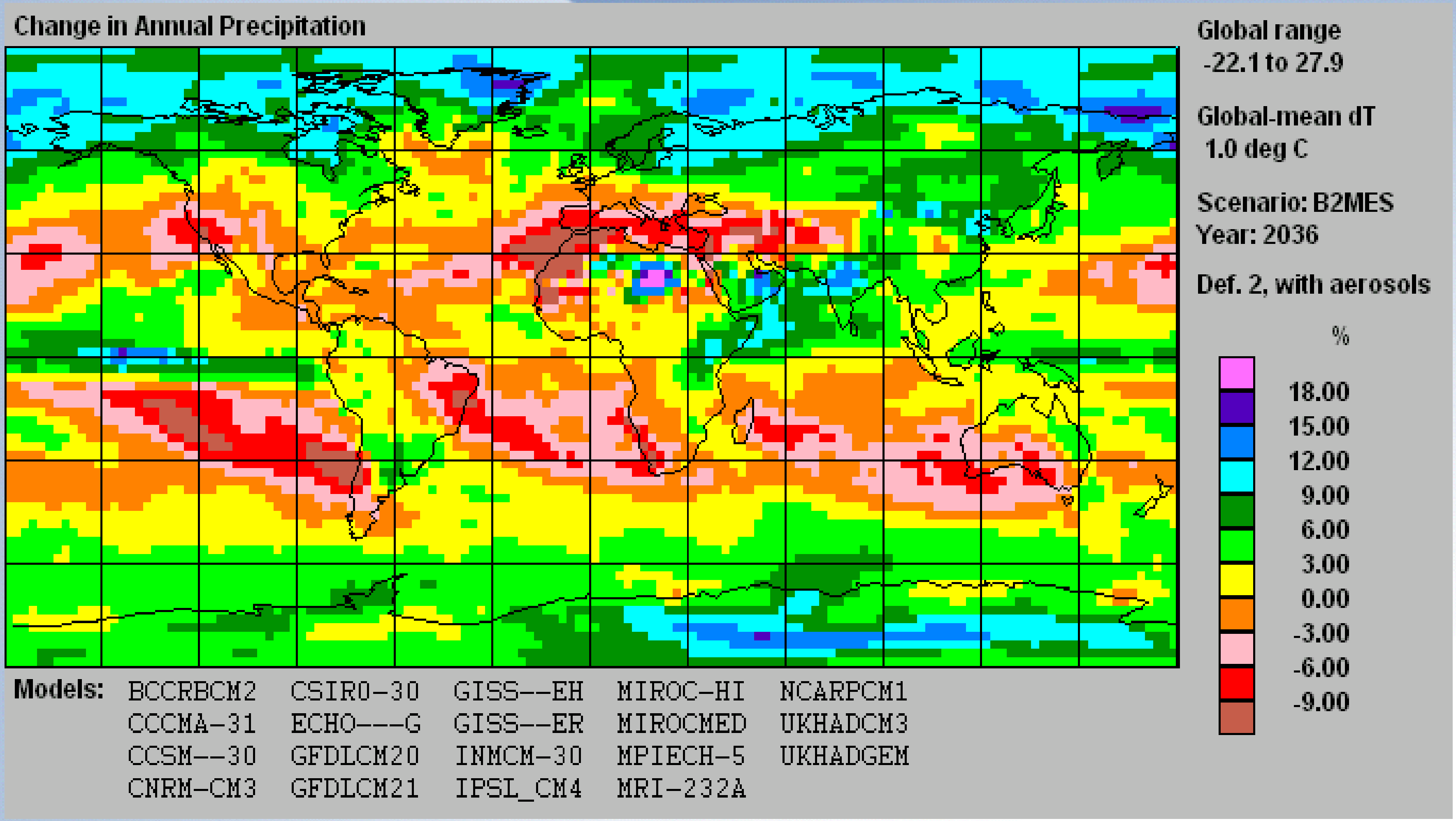
Outline

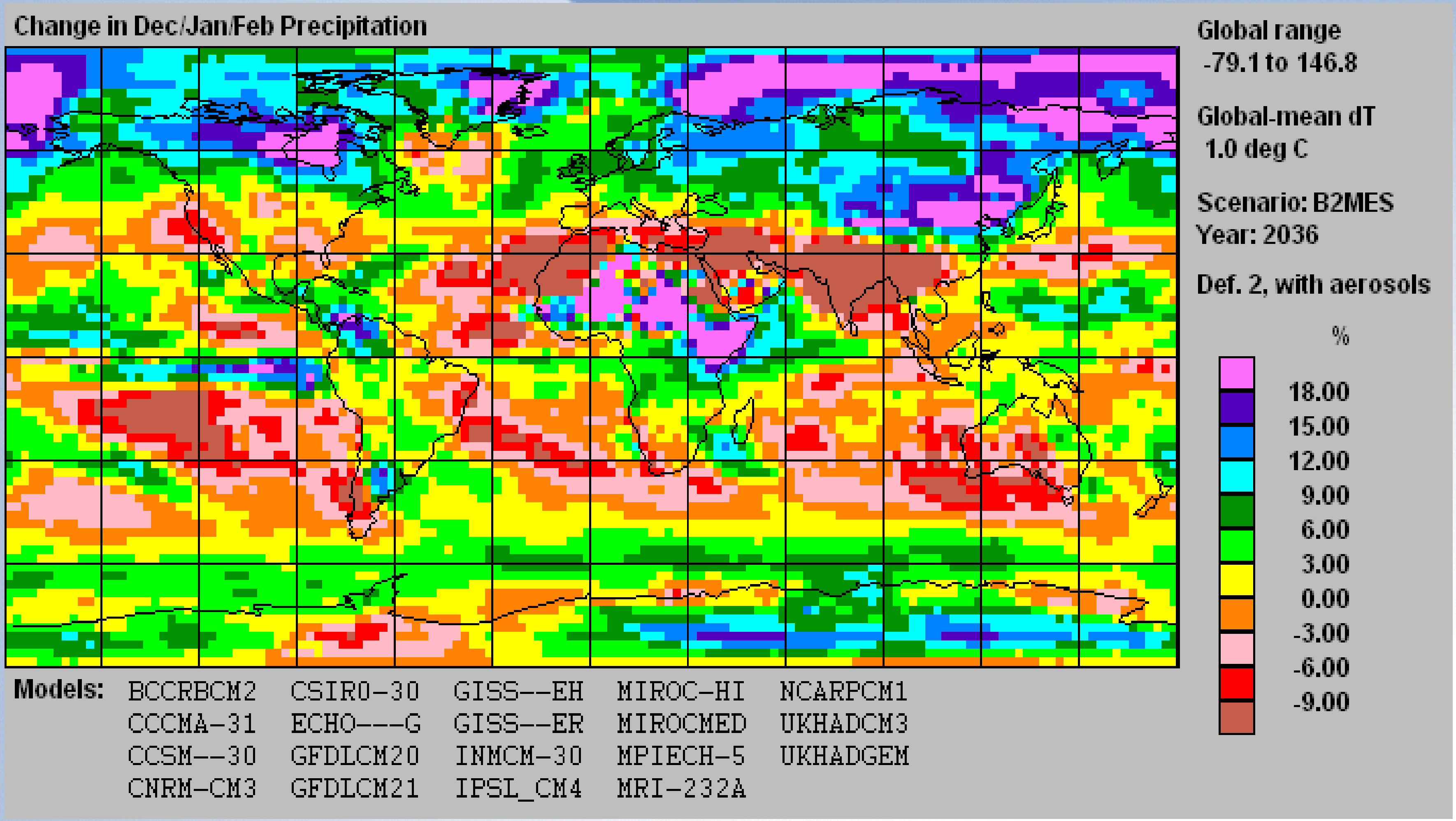
- Future precipitation changes for California
- Model validation – how good are AOGCMs at simulating present-day precipitation?
- Simulation of western boundary fluxes
- Effect of ENSO on boundary fluxes
- Conclusions

WHAT DO AOGCMs SAY ABOUT FUTURE PRECIPITATION?

Average annual precipitation change (%)



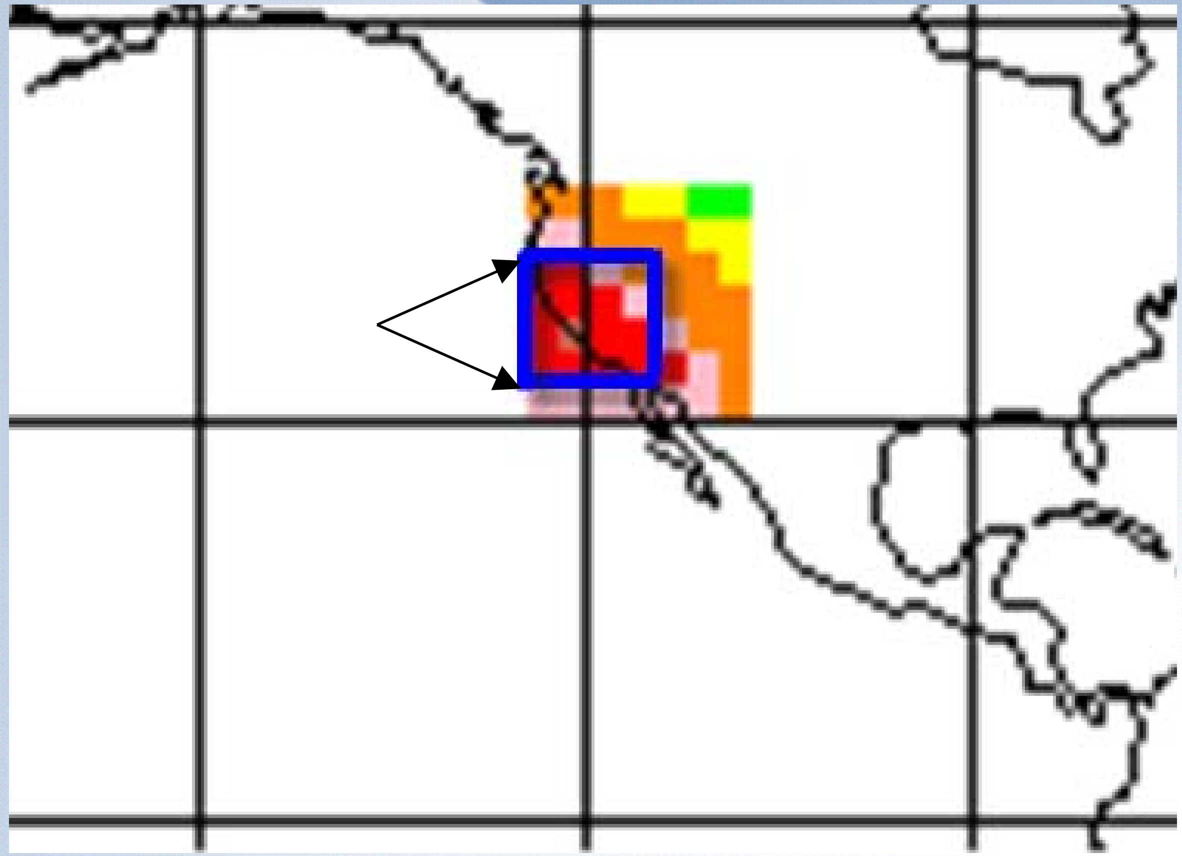
Average DJF precipitation change (%)



SUMMARY OF RESULTS FOR CALIFORNIA

(DJF: 42.5–52.5N, 115–125W)

Area used for defining precipitation change



Summary of DJF precipitation change results for California

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*** SCALED AREA-AVERAGE CHANGE RESULTS FOR INDIVIDUAL MODELS ***

AEROSOLS ARE INCLUDED IN THESE RESULTS

*** 20 MODELS : VARIABLE = PRECIP -- LINEAR SCALING : SEASON = DJF

*** DEFINITION 2 RESULTS ONLY *** : 20 CASES
*** MAGICC MODEL = DEFAULT : SCENARIO = REFRNCE : YEAR = 2036
*** TOTAL GLOBAL-MEAN Delta-T =    .998 degC

GRID BOX CENTRAL POINTS (2.5deg by 2.5deg GRID)
LATITUDE RANGE  =   32.5 TO   42.5 degreesN
LONGITUDE RANGE = -125.0 TO -115.0 degreesE


MODEL = BCCRD2 : AREA AVE =  11.011  (%)
MODEL = CCMAD2 : AREA AVE =   -.789  (%)
MODEL = CCSMD2 : AREA AVE =   6.647  (%)
MODEL = CNRMD2 : AREA AVE =   2.102  (%)
MODEL = CSIRD2 : AREA AVE = -11.480  (%)
MODEL = ECHOD2 : AREA AVE =  -3.309  (%)
MODEL = FGOAD2 : AREA AVE =  -5.653  (%)
MODEL = GF20D2 : AREA AVE = -14.474  (%)
MODEL = GF21D2 : AREA AVE =  -5.518  (%)
MODEL = GIEHD2 : AREA AVE = -11.726  (%)
MODEL = GIERD2 : AREA AVE = -19.138  (%)
MODEL = INMCD2 : AREA AVE =   7.521  (%)
MODEL = IPSLD2 : AREA AVE = -11.844  (%)
MODEL = MIHID2 : AREA AVE =  -7.889  (%)
MODEL = MIMED2 : AREA AVE = -26.210  (%)
MODEL = ECH5D2 : AREA AVE = -14.281  (%)
MODEL = MRI2D2 : AREA AVE =  -6.740  (%)
MODEL = PCM1D2 : AREA AVE =   -.324  (%)
MODEL = HAD3D2 : AREA AVE = -14.500  (%)
MODEL = HADGD2 : AREA AVE = -10.249  (%)

MODEL = MODBAR : AREA AVE =  -6.842  (%)
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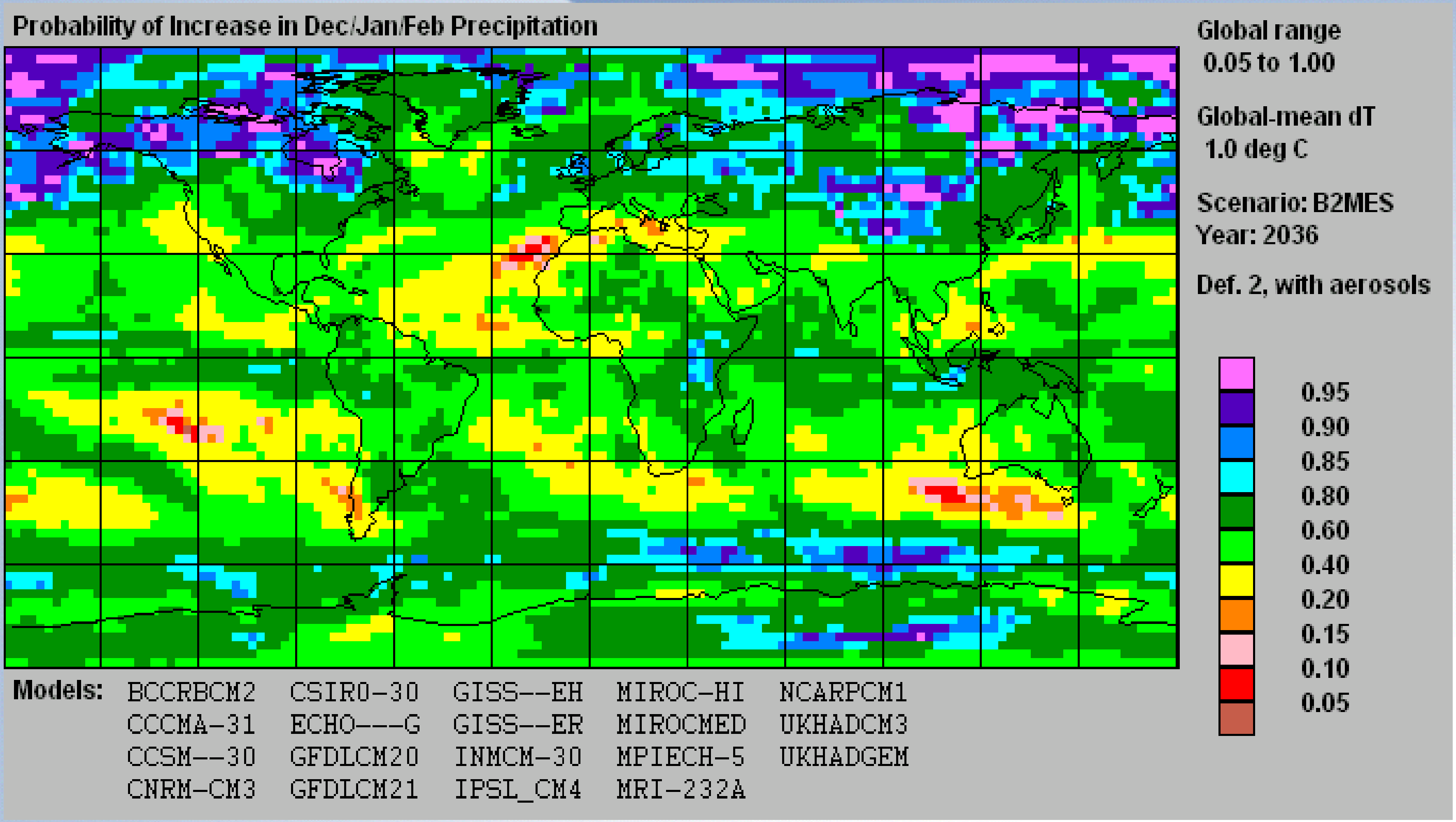
4 models show increase, 14 models show decrease.

Average decrease, 6.8% per 1degC global warming.

Probability of precipitation increase: DJF

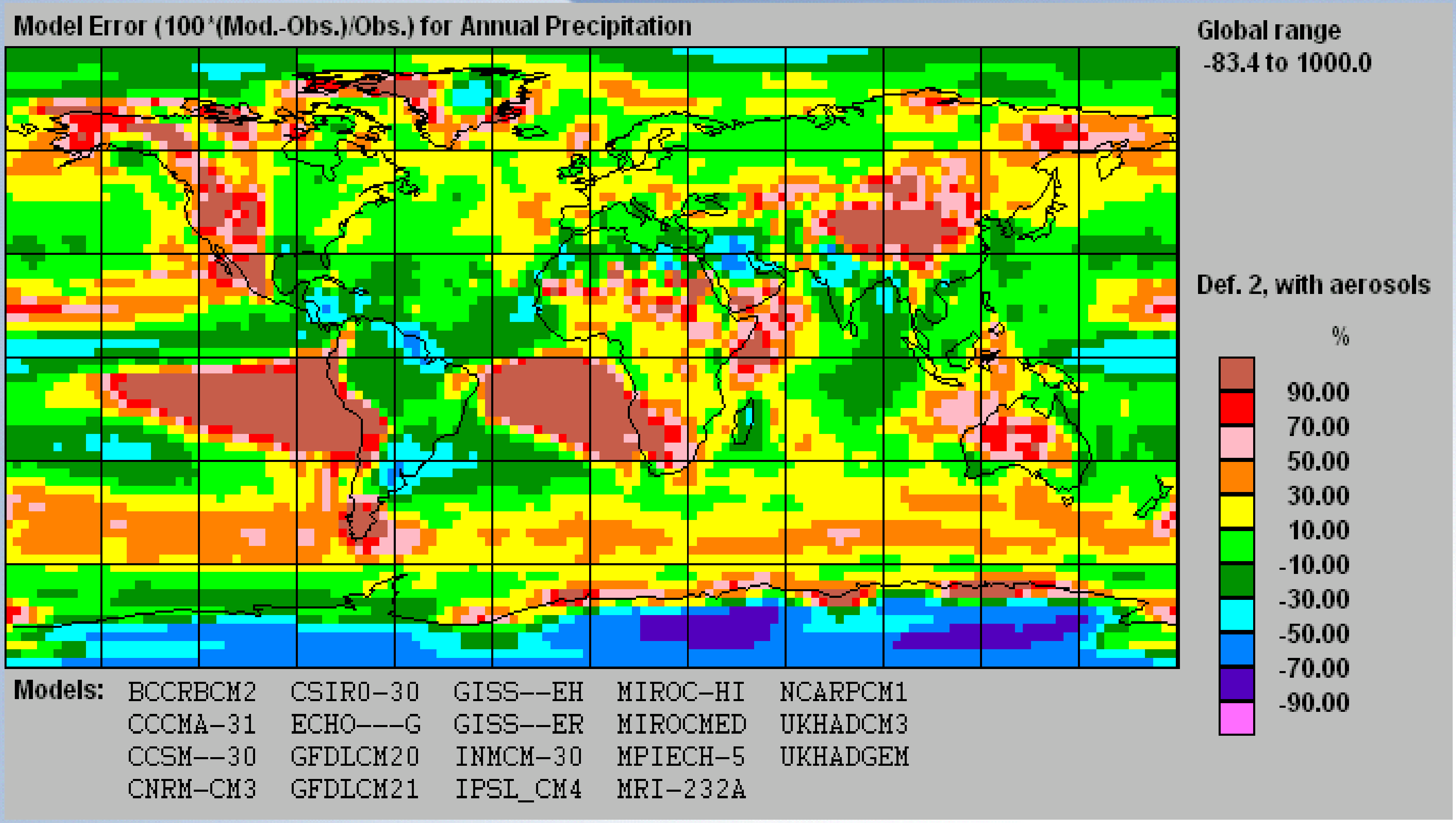


CA precipitation change summary

- On average, models show reduced precipitation
- There are considerable inter-model differences
- Based on these differences, the odds in favor of reduced precipitation are about 2:1

HOW GOOD ARE MODELS AT SIMULATING PRESENT-DAY PRECIPITATION?

% precipitation error, annual: Average over 19 AR4/CMIP3 models



% precipitation error, DJF:
Average over 19 AR4/CMIP3 models

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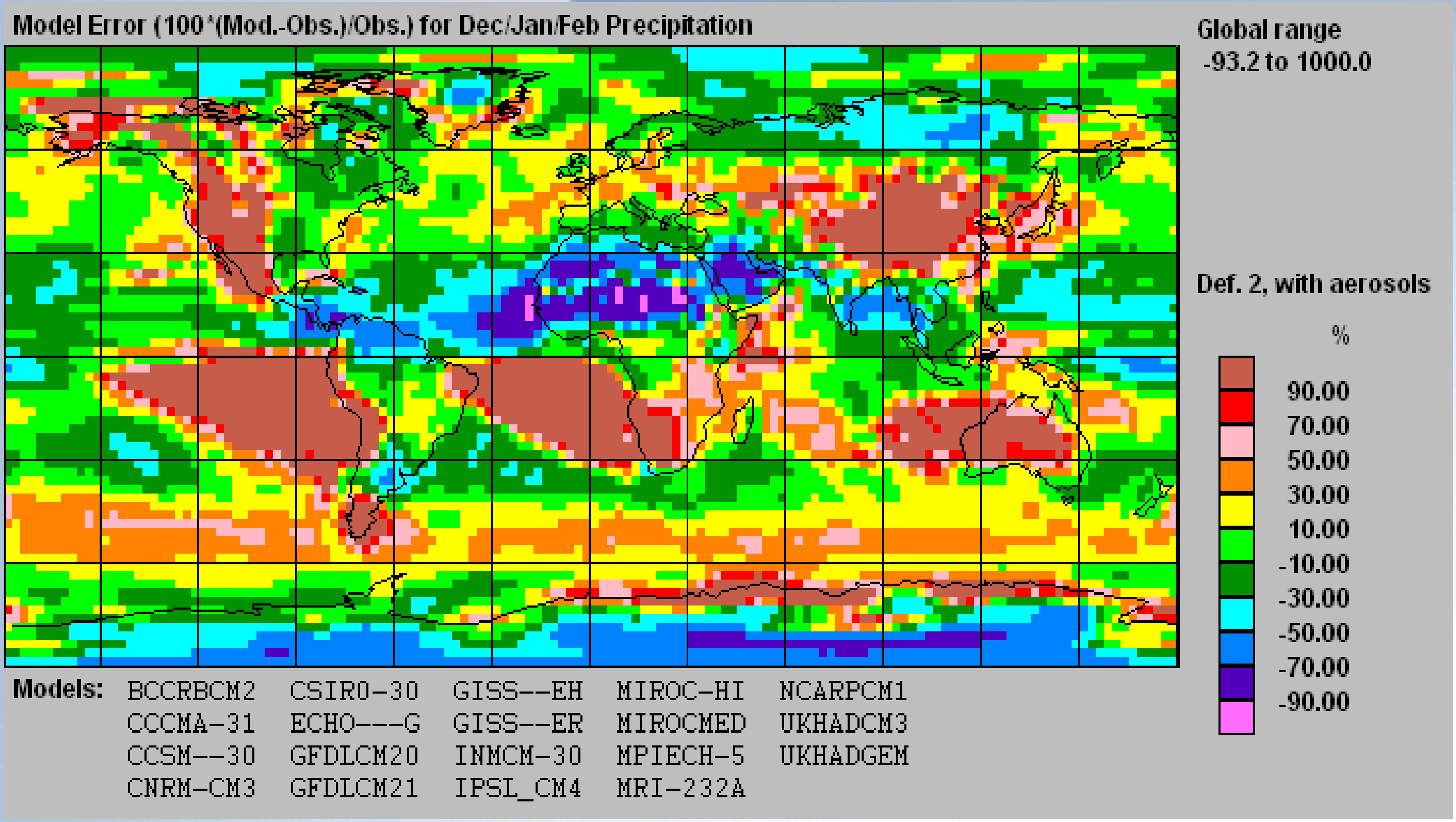
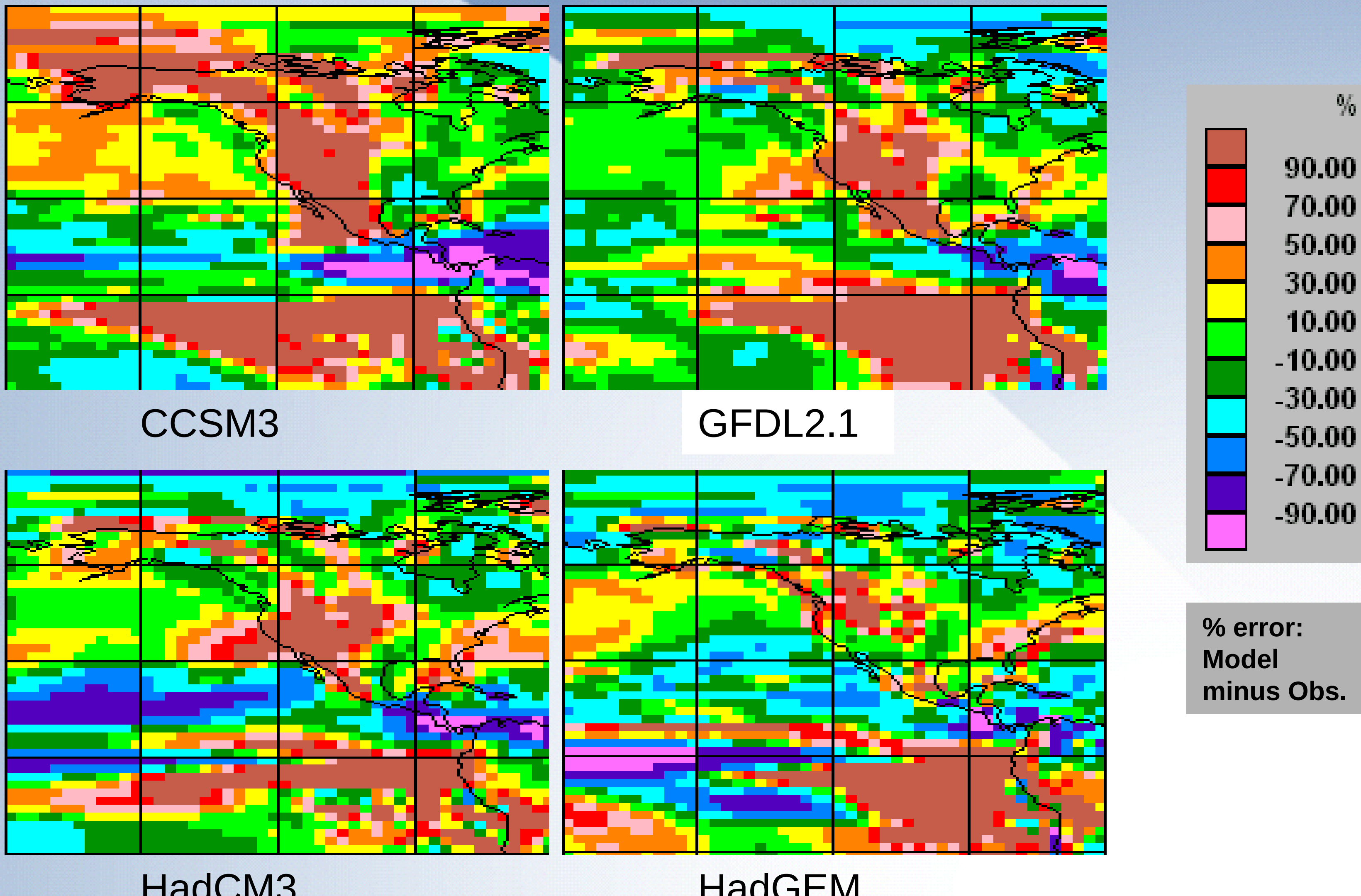
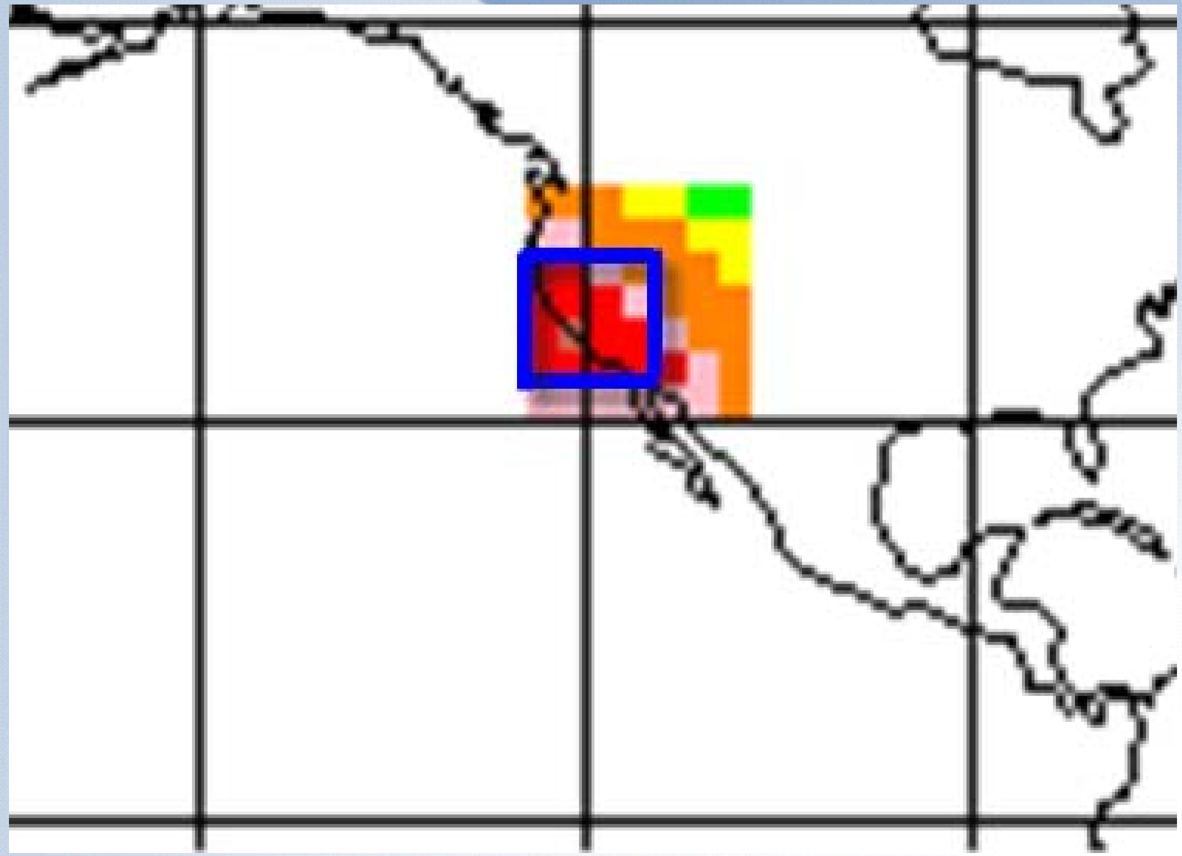


DJF precipitation errors: Individual models



PRECIPITATION VALIDATION OVER THE CALIFORNIA REGION

Areas used for model validation



Model/observed precipitation comparison

				Pattern Correl.			Bias	
RANK	MODEL	Flux Adj?	Globe	49 boxes	16 boxes	Globe	49 boxes	16 boxes
1	MRI	YES	0.886	0.936	0.973	-0.084	0.559	0.895
2	GFDL2.0		0.868	0.887	0.923	0.091	1.285	1.792
3	HadGEM		0.797	0.934	0.951	0.385	0.745	0.477
4	MIROChi		0.800	0.899	0.926	0.281	1.909	2.283
4	ECHAM5		0.808	0.900	0.905	0.247	1.390	1.621
6	ECHO-G	YES	0.910	0.868	0.831	0.128	0.813	0.777
7	HadCM3		0.858	0.829	0.946	0.230	1.501	2.545
8	CCCMA	YES	0.888	0.884	0.827	-0.010	0.786	0.820
9	GFDL2.1		0.857	0.864	0.886	0.215	1.504	2.107
10	IPSL		0.808	0.854	0.927	-0.090	1.616	2.663
11	CSIRO		0.814	0.867	0.870	-0.161	1.512	1.730
12	CNRM		0.772	0.857	0.909	0.540	0.787	0.697
13	CCSM3.0		0.797	0.848	0.856	0.160	1.231	1.116
14	PCM1		0.665	0.894	0.830	0.343	0.867	0.824
15	MIROCmed		0.833	0.824	0.694	0.035	1.002	0.796
16	GISS-ER		0.774	0.845	0.843	0.297	1.589	2.236
17	FGOALS		0.816	0.619	0.431	0.307	2.465	2.248
18	BCCR		0.793	0.794	0.801	0.307	0.409	0.085
19	INM	YES	0.700	0.783	0.669	0.116	0.963	0.892
20	GISS-EH		0.733	0.492	-0.066	0.340	1.185	1.278
	Model mean		0.910	0.906	0.892	0.184	1.206	1.394

Rank based on cumulative correlation rank.

Best 3 in blue.

Worst 3 in red.

Bias in mm/day, model minus obs.

(1 mm/day = 14.4 in./yr)

Globe uses annual precipitation. Regions use DJF precipitation.

Precipitation validation summary

- Models show a strong positive bias (i.e., they are too wet)
- There are very large differences in model skill

SIMULATIONS OF FLUXES AT THE WESTERN BOUNDARY (CCSM3.0 vs Reanalyses)

Boundary is at 130W, from 20–55N

Calculating fluxes

The monthly-mean westerly flux for variable X at a given height and latitude is defined by

F = <uX>

where u is the westerly wind component, and < > denotes the average over a month of values of u and X taken at 6-hourly intervals.

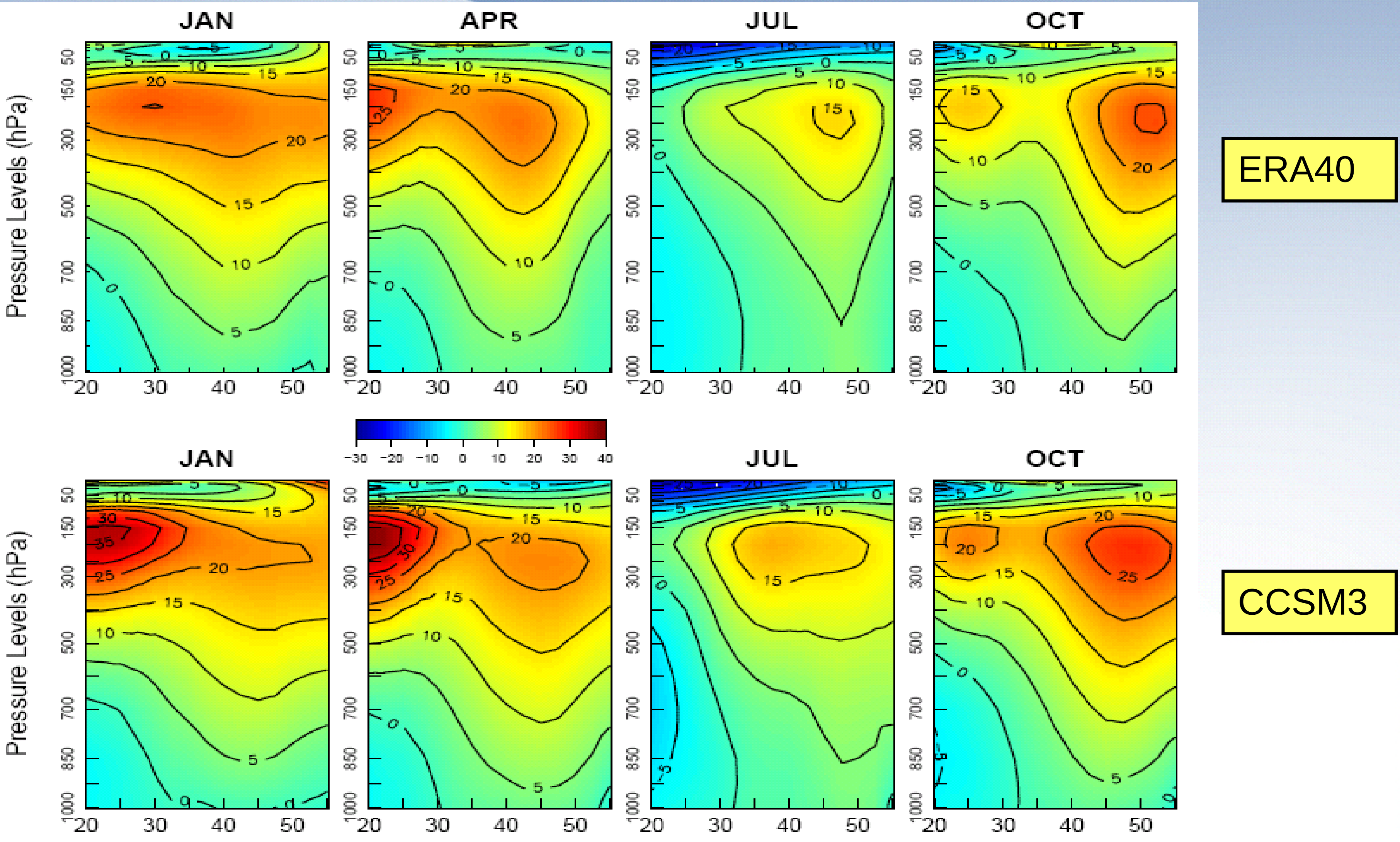
Heat flux = <uT>

Moisture flux = <uq>

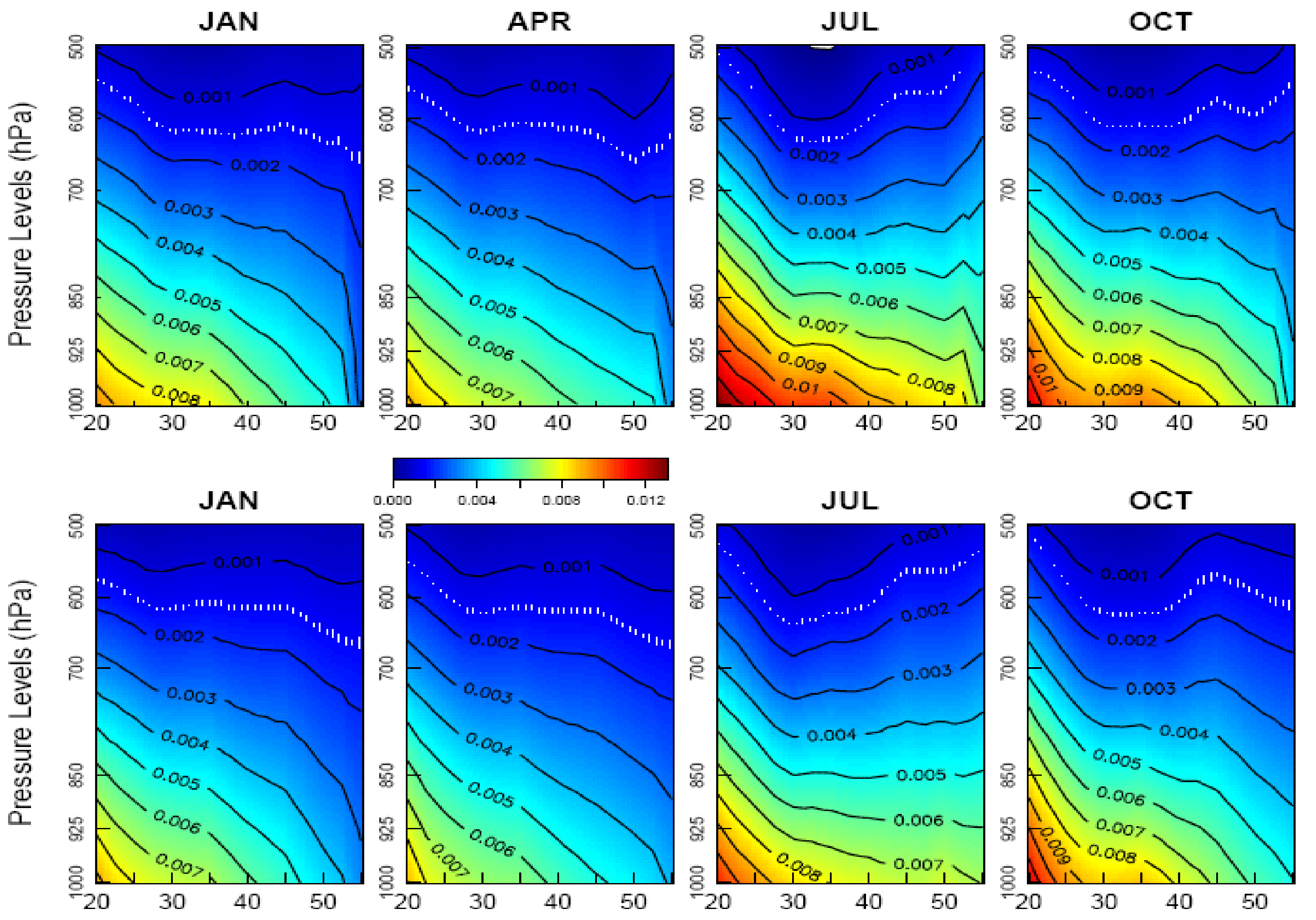
Momentum flux = <uu>

Note that <uX> ≠ <u><X>, but time series of these two quantities are highly correlated.

Westerly windspeed at 130W



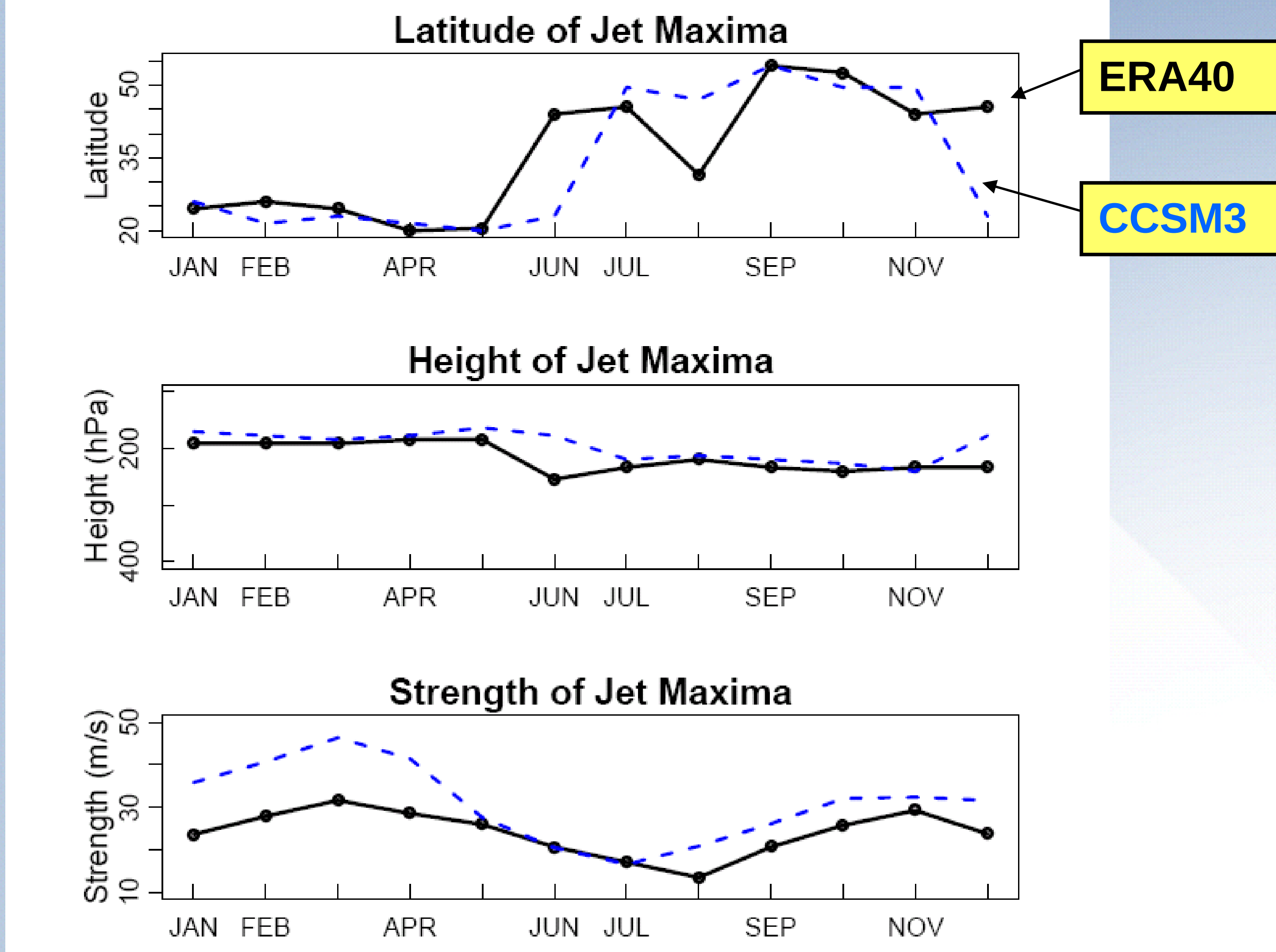
Moisture flux at 130W



ERA40

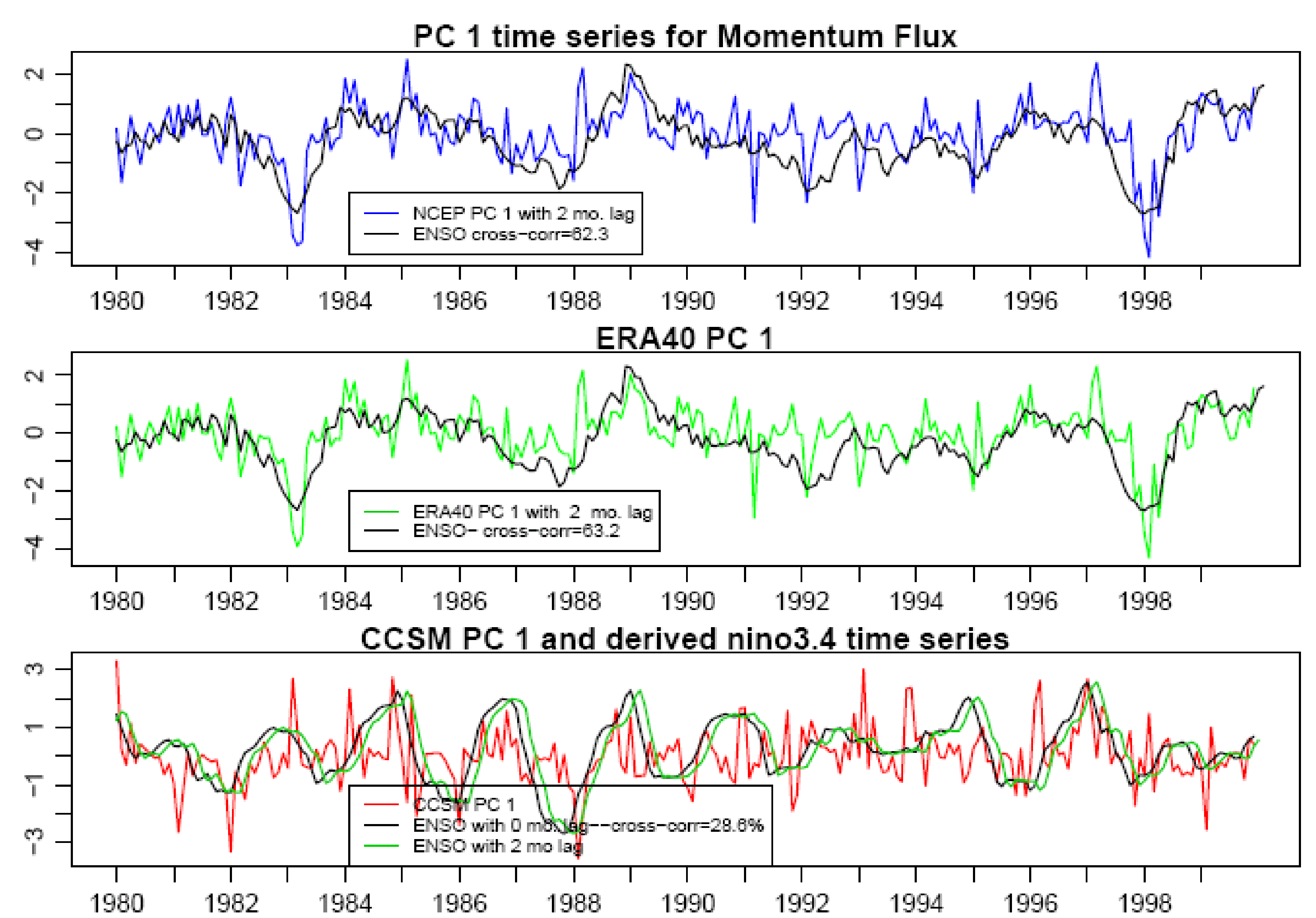
CCSM3

Model vs observed comparison of jet characteristics

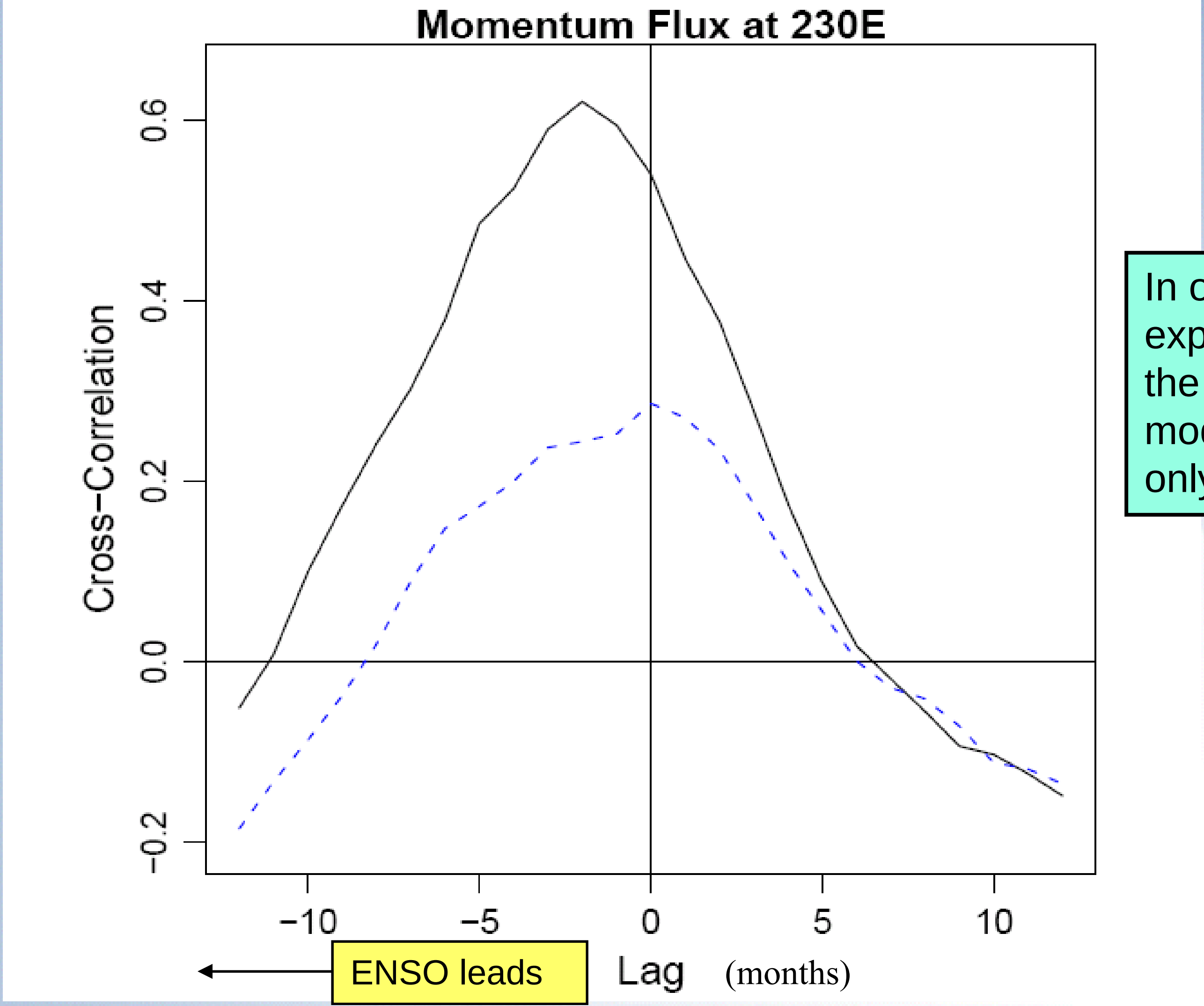


EFFECT OF ENSO ON FLUXES

Dependence of momentum flux on ENSO



Lag correlation: momentum flux vs ENSO



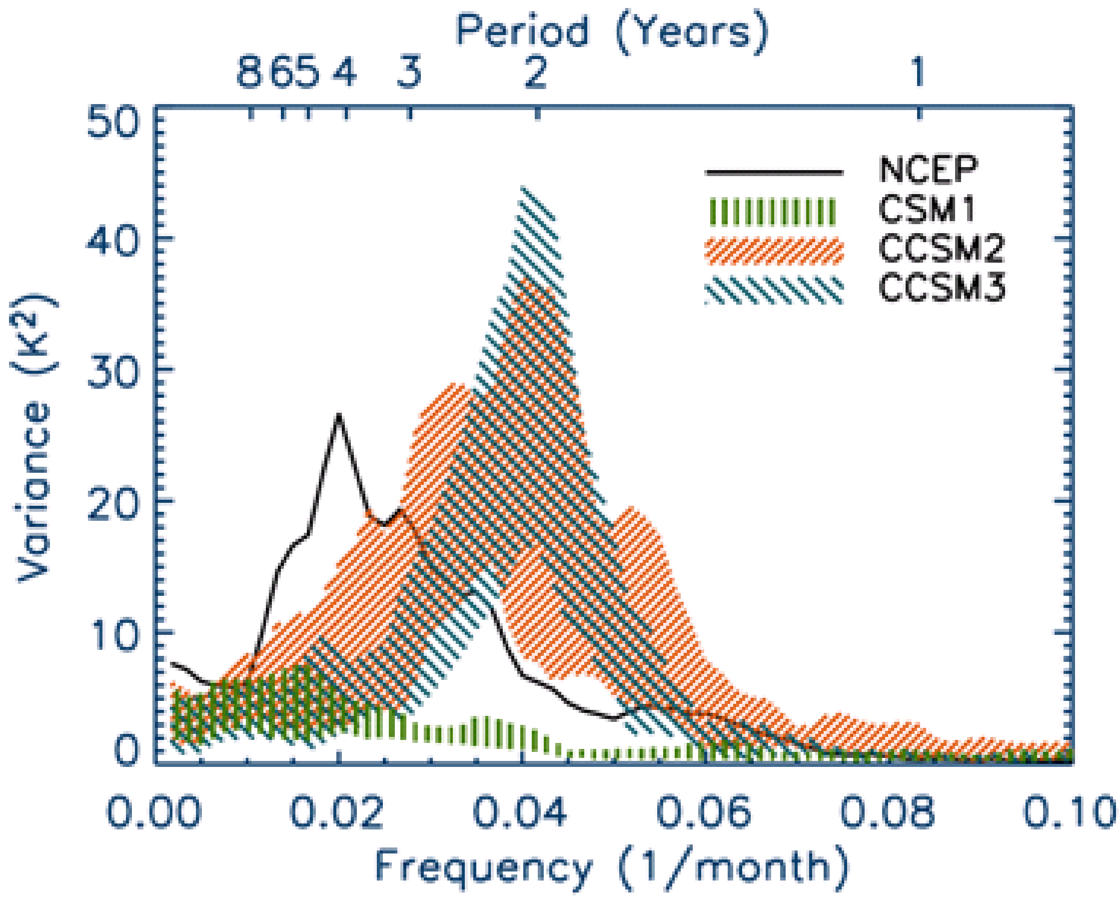
In observations. ENSO explains almost 40% of the variance. In the model, ENSO explains only 8% of the variance.

Summary of ENSO effects

- Observed flux variability is significantly related to ENSO
- The model shows a much weaker relationship
- In order to reliability estimate future inter-annual and inter-decadal precipitation variability we must ….
  - Improve the ENSO-flux link in models
  - Improve model simulations of ENSO

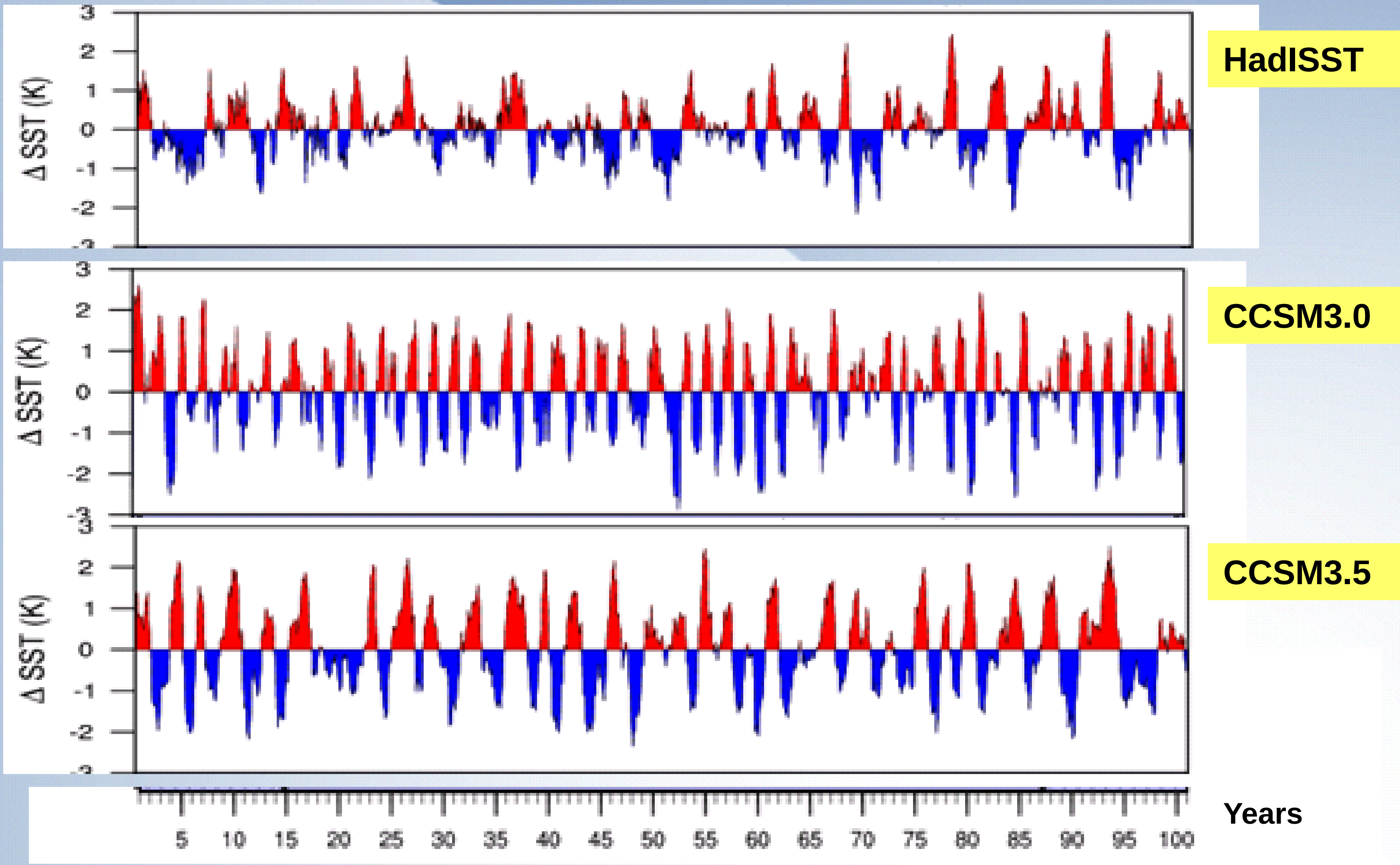
ENSO IMPROVEMENTS

Improvements in Nino3 SST power spectra



Gent and Kiehl, 2004; Collins et al, 2006

Improvements in ENSO (Nino 3) SST simulations



From Jerry Meehl, NCAR

Summary and conclusions

- Based on inter-model differences, the odds are approximately 2:1 that precipitation will decrease in California
- In simulating present-day precipitation, all models appear to be biased high
- In one model (CCSM3), simulations of the jet are reasonable
- In CCSM3, moisture flux simulations are also reasonable, but the fluxes tend to be less than in the re-analyses
- CCSM3 significantly under-estimates the effect of ENSO on fluxes.

Thankyou